Spatial-temporal patterns of childhood immunisation in New Zealand (2006–2017): an improving pattern but not for all?

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Abstract

Background: Declining childhood immunisation represents a serious public health problem globally, and in New Zealand. To guide efforts to increase immunisation coverage, this study monitors nationwide change in immunisation coverage since the introduction of the National Immunisation Register (NIR) in 2005 and spatiotemporal patterns of immunisation coverage from 2006 to 2017.

Methods: The study population consisted of 4,482,499 individual immunisation records that were obtained from the NIR (2005–2017). Data on yearly and average immunisation coverage in census area units (CAUs) in New Zealand were calculated by milestone age (6/8/12/18/24/60/144 months). Data for 2005 were excluded due to missing records in the introductory period of the NIR. We analysed spatial and spatiotemporal patterns using Gi* and SaTScan methods.

Results: Immunisation coverage improved since the introduction of the NIR in 2005, reaching a peak in 2014 and 2015 with a slight decrease in 2016 and 2017. Well and insufficiently immunised areas were identified with spatial autocorrelation analyses highlighting several hot- and cold-spots. Comparison of CAUs with neighbouring CAUs allowed for the identification of places where immunisation coverage was significantly higher or lower than expected, over both time and space.

Conclusion: We provide the first spatiotemporal analysis of childhood immunisation in New Zealand that utilises a large sample of over 4.4 million individual immunisation records. Our spatial analyses enable policymakers to understand the development of childhood immunisation coverage and make more effective prevention strategies in New Zealand.

Keywords: Immunisation coverage; New Zealand; spatiotemporal pattern; mapping; national registers.

1. Introduction

Universal vaccination programmes that increase immunisation coverage have reduced the burden of infectious diseases in both developing and developed countries[1] and the benefits of childhood vaccinations are now scientifically unquestioned[2]. However, while immunisation coverage has improved in many parts of the world, recent outbreaks serve to remind us just how these gains can be lost.[3] Over the course of 2018, four of the six World Health Organization (WHO) regions had substantial measles outbreaks, and measles was once again endemic in every region of the world.[3] Declining immunisation coverage was said to be related to supply shortages and growing vaccine hesitancy.[4] In another example, the United Kingdom (UK) has also seen a decrease in coverage of the measles-mumps-rubella vaccine to 91.2%, the fourth annual decline in a row and to its lowest level since 2011–12.[5] Collectively, this evidence highlights the significant and urgent need for surveillance of immunisation coverage in developed countries such as New Zealand.

Research on immunisation often focuses on attitudes towards immunisation[6], surveillance and outbreaks events[7,8] or uses survey-based methods[9]. Several pioneering global epidemiological studies have painted a picture of immunisation coverage with a broad brush; however, these studies often focus on developing countries and rarely depict detailed patterns that show within country or region variability which are important in developed countries such as New Zealand to inform research and policy.[2,10,11] Indeed, several highly powered studies acknowledge that immunisation coverage is likely to show variability within the larger geographical areas that were analysed.[10,12,13] Data at fine geographical scales and analyses that examine change over time are required to fully understand patterns of local immunisation coverage. Understanding where and why immunisation coverage may be declining over time and space is important as these areas can be at risk of losing their herd immunity.

Emerging evidence utilising geospatial analyses have shown clusters of low immunisation coverage.[14–17] In one of the only spatiotemporal analyses investigating vaccine hesitancy, the largest increases were shown to have occurred in a relatively small proportion of regions throughout the state of California.[11] Despite this emerging evidence, few studies to the authors knowledge have examined such spatiotemporal complexities using nationwide registry data.[11] We extend evidence by using National Immunisation Register (NIR) data from 2006 to 2017 at a fine geographical scale (i.e. census area unit) in a sample of over 4.4 million childhood immunisation records from across New Zealand. This study investigates how immunisation coverage has developed in New Zealand since the introduction of the NIR in 2005. It then examines nationwide spatial and spatiotemporal trends and patterns of immunisation coverage.

2. Methods

2.1 Data

The New Zealand Ministry of Health provided the NIR for the years 2005–2017 at the meshblock geographical level (with identifiers of higher administrative units), including information about sex, prioritised ethnicity, milestone age in months, milestone year and milestone month, and census year. The full data consisted of 4,362,674 records representing an aggregation of 4,482,499 individual immunisation events. From those only events of fully immunised children were extracted (3,341,715 records of 3,438,236 events). Data from 2005 was excluded from the analysis due to numerous missing records. All analyses were performed at the level of census area units (CAUs) geographies, based on the information about residency meshblock of the immunised children. CAUs are census administrative areas that, in urban areas, contain 3,000 to 5,000 people (2,004 CAUs in 2013). The birth data in CAUs were provided by Statistics New Zealand and included the number of live-born children in CAUs between 2005 and 2018. These counts were rounded to the base of three to ensure the confidentiality of individuals before providing the official data.

2.2 Calculation of rates and trends of immunisation coverage development over time

Counts of immunisation events and counts of live-born children were aggregated in CAUs. The immunisation rates for each milestone age (6/8/12/18/24/60/144 months) and year (2006–2017) were calculated as a percentage of fully immunised children and the total amount of children of applicable milestone age for each area. The month of immunisation and month of birth were considered to calculate the milestone age-specific immunisation since.

2.3 Spatial and spatiotemporal trends and patterns in immunisation coverage

The analysis of spatial and spatiotemporal autocorrelation enables the identification of areas that perform better or worse than their local neighbourhoods. This study investigated spatial and spatiotemporal trends and patterns of milestone age-specific immunisation coverage around New Zealand between 2006 and 2017. We used local Gi*[18] to explore local spatial autocorrelation in the data. It is used as an indicator of local clustering that measures a concentration of spatial data[19] allowing for subsequent visualisation of the location of identified clusters[18]. The results distinguish between statistically significant clusters (*p-value < 0.05*) of high and low immunisation rates. We used the second-order queen's contiguity scheme of the neighbourhood to obtain spatial weights for individual CAUs.[20] GeoDA software package[21] was used for the processing of the data and computing of the measures while QGIS 3.2[22] was used for geovisualisation of the clusters.

Spatiotemporal scan statistics were then used to identify clusters of high and low rate areas simultaneously over space and time. This was processed using the open-source software SaTScan 9.3.[23] QGIS 3.2 was used for geovisualisation of clusters. Input data consisted of: (1) immunisation events aggregated into CAUs and grouped by year of the event; (2) demographic structure of CAUs represented by aggregated counts of births in CAUs; and (3) coordinates of CAU centroids. The retrospective space-time analysis of high and low rate clusters was based on input data applying the Discrete Poisson model.[24] SaTScan was set to find clusters within a dynamic circular window including up to 10% of the population, while the maximum time span of the cluster was set to 90% of the study period. These values were selected due to focusing on rather small areas appearing long-term in time while trying to eliminate areas with an early deployment of NIR. We adjusted for the time by non-parametric stratified randomization to ensure the comparability of rates within various time periods.[25] Resulting indirectly standardised rates (expressed as the relative risk) for each identified geographic

cluster were estimated, and only significant clusters (*p-value ≤ 0.001*) remained in the results. The clusters consisting of only one CAU, as well as clusters appearing for a period of the first reliable year (2006 for 6/8/12-months milestone age, 2007 for 18/24-months milestone age and 2010 for 60-months milestone age), were not considered due to the early introduction period of the NIR.

3. Results

3.1 Mapping of immunisation coverage and exploratory analysis using spatial autocorrelation

Animated maps depicting the immunisation coverage for each milestone age can be found in the supplementary online materials (Supplementary Figure 1). In the years following the introductory period of the NIR (2005–2006), the overall immunisation coverage grew, more in the South Island than the North Island until reaching a peak in the years 2014 and 2015. A slight decrease in immunisation rates are visible since then. Immunisation rates are generally lower for milestone ages of 6, 8 and 18 months than for "complete years" milestone ages of 12, 24 and 60 months. However, the immunisation rates at 8-months milestone age recorded the most rapid development in terms of improvement levelling the 12-months milestone age immunisation uptake during recent years.

Figure 1 shows clusters of CAUs with an average immunisation coverage significantly different from their neighbourhood CAUs. Clusters of cold-spots of low immunisation coverage (purple shade) can be found within the major population centres of Auckland, Christchurch and Wellington regardless of the milestone age that is assessed. Cold-spots are the most notable for the immunisation coverage at 6-months milestone age with large cold-spots identifiable in Northland and through the central North Island. This observation was also found for 18-months milestone age. The persisting cold-spots are not age specific, except 6-months milestone age located in the north-west coast region. Most hot-spots (light green shade) are found in rural areas of the central South Island. Both hot- and cold-spots are

generally smaller for 8/12/24/60-months milestone age immunisation coverage than for 6- and 18-months milestone age.

Figure 1 Hot- and cold-spots of average immunisation coverage by milestone age

3.2 Spatiotemporal patterns

The following set of geovisualisations (Figure 2) represent spatiotemporal clusters of CAUs. Resulting significant clusters (*p-value ≤ 0.001*) indicate higher (positive) or lower (negative) levels of immunisation coverage when compared to neighbouring CAUs. The geovisualisations within Figures 2 locate the cluster on the map while Supplementary Tables 1–6 in the supplementary material provide information on the start and end years of individual clusters, number of CAUs included, number of expected immunisation events and observed immunisation events, and the type of the cluster. The colours of the column match the colours in the maps.

Spatiotemporal clusters of CAUs with low immunisation coverage were generally identified in densely populated areas of big cities such as Auckland, Christchurch, and Wellington as well as in the central North Island. A high number of clusters identified by individual analyses of milestone age-specific immunisation coverage indicates considerable spatial variation in the case of immunisation at 6, 8 and 18-months when compared to immunisation coverage at 12, 24 and 60-months (Figure 2, Supplementary Figure 2 shows animated full resolution maps). Clusters of low immunisation coverage were not found elsewhere in the South Island other than in Christchurch urban area regardless of the milestone age. All maps and tables showing and describing spatiotemporal clusters are located in the supplementary online material.

Figure 2 Geovisualisation of spatiotemporal clusters of immunisation coverage in New Zealand

Main urban centres of Auckland, Christchurch and Wellington

Many of the spatiotemporal clusters, of both low and high immunised areas, appeared in Auckland and Counties Manukau. However, most of these clusters are historical since they had lasted for a certain time and ended earlier than 2017 (Supplementary Tables 1-6). This means local differences of immunisation coverage in the area slowly disappeared. The split between the eastern coast (higher immunisation rates) and western coast (lower immunisation rates) is evident around Auckland in the case of 6, 8 and 18-months immunisation coverage. Only two historical clusters of low immunisation coverage were identified at 12 and 24-months milestone age. However, three persisting bigger clusters emerged on the west coast when looking at 60-months milestone age.

No clusters were detected in Wellington for immunisation coverage at 12-months and 60-months milestone age. However, a temporary cluster (2006/2007–15) of low immunisation covering in the central city appeared for the remaining milestone ages of 6/8/18 months. Cluster 14 was classified as persisting in case of immunisation coverage at 24-month milestone age (Figure 2, Supplementary Table 5). A similar situation was found in Christchurch with differences being a pair of clusters instead of a single cluster. All clusters in Christchurch were temporary. The clusters of high immunisation rates were regularly detected in semi-rural areas south of Christchurch.

Other areas

A large persisting cluster of low immunisation coverage at 6-months milestone age was located in Northland. However, no clusters were identified for other milestone ages. The central North Island seems to be the region where clusters of low immunisation coverage were detected most often, they were also the largest ones. Although most of the clusters (regardless of the milestone age) lasted only for a limited time, the Bay of Plenty area seems to underperform in long-term immunisation coverage at 6, 18 and 60-months milestone age. The situation is analogous in the case of Lakes District Health

Board in the central North Island where a persisting cluster of low immunisation coverage was identified for 6-, 24- and 60-months milestone age (Figure 2).

Clusters were often identified in urban areas of Hamilton and Tauranga. Mostly clusters of high immunisation coverage persisting over time were detected in Tauranga for milestone ages of 18-, 24- and 60-months. The situation in Hamilton (and its vicinity) seems to be more complex. Both types of clusters assessed as persisting were located there. However, clusters of CAUs with low immunisation coverage generally appeared in the central urban area while high immunisation clusters were located in rather suburban areas around the outskirts.

4. Discussion

We provide the first nationwide spatiotemporal investigation of childhood immunisation in a large sample of over four million individual immunisation records from 2005 to 2017 across New Zealand at fine geographical scale. We respond to calls to monitor change in immunisation over time[26] and extend knowledge by showing spatiotemporal changes in immunisation coverage. This study shows that since the introduction of the NIR in New Zealand, immunisation coverage has improved significantly reaching a peak in the years 2014 and 2015. However, a slight decrease in immunisation coverage is visible from 2015 to 2017. This study also demonstrates several areas of spatial autocorrelation. For example, several cold-spots where there are clusters of CAUs with lower immunisation coverage than in their neighbouring CAUs were identified in the major population centres of Auckland, Christchurch and Wellington regardless of the milestone age. Finally, this study contributes significantly to evidence by highlighting how spatial clusters of high and low immunisation change over time. We provide specific evidence for policy by highlighting the start and the end of individual clusters, number of CAUs included, and the number of expected immunisation events and observed immunisation events.

Emerging evidence suggests that areas of low immunisation coverage cluster geographically.[17,27,28] For instance, US evidence from California showed that of 50,233 children in the study population evaluated (2010 to 2012), 10,144 (21%) were identified as being within a cluster of low immunisation.[17] Despite this, previous evidence is often restricted by smaller sample sizes,[29] coarse geographic scales,[26] limited geographical extents,[30] limited temporal scope,[31] and often by not simultaneously investigating both spatial and temporal complexity culminating in spatiotemporal trends. Our nationwide and spatiotemporal findings over a decade provide important evidence that help identify clusters of immunisation over time. Findings also help policymakers understand the development of childhood immunisation in New Zealand and help them to focus future efforts to increase vaccination coverage in specific geographical areas. This is important as previous evidence shows that low immunisation is associated with elevated risk of various outbreaks including measles and pertussis.[32–34]

Child wellbeing and better population health outcomes, supported by a strong and equitable public health system, are key priorities for the New Zealand Ministry of Health in 2019/20[35]. In order to evaluate progress on these priorities, empirical evidence detailing each stage of childhood is needed. Thus, by considering temporal and spatial patterns at different stages of children's lives, we are able to provide a comprehensive picture of child wellbeing and inform policy directed towards government priorities. Our findings assist both the Ministry of Health and regional district health boards in directing resources to either geographic areas or specific populations to improve health outcomes for children overall.

Our retrospective analyses help to better understand national and regional evaluation of the efficacy of immunisation campaigns and outreach activities. Findings also enable improved area-specific understandings of policy and resource allocation. However, recent evidence suggests existing structural, economic, cultural and other factors are possible barriers to health care access[36] and

immunisation[37]. Hence, findings should be paired with information on the socioeconomic and demographic structure of clusters to identify not only places where it may be most appropriate to intervene, but also an appropriate intervention strategy (e.g. cultural). Locations of well-immunised child populations (hot-spots) indicate areas of good health outcomes for children. Consequently, such areas put less pressure on the health system due to healthier populations that are resilient to outbreaks of preventable diseases.

Our findings should be interpreted in light of study limitations. While NIR data were obtained from 2005–2017, the first years (2005 and 2006) were often not usable due missing data. This reflects a real-world scenario where the introduction of a reporting system such as the NIR needs time to be implemented. While data were harmonised to reflect the change of census geographies the milestone ages of immunisation schedules are not always round years. This means the number of children born in CAUs needed to be recalculated in order to comply with reporting of immunisation events in CAUs. For instance, children born in July or later are usually fully immunised during the following calendar year in the milestone age of 6 months. In addition to this, data used for the estimation of immunisation rates did not account for people's mobility and therefore did not consider if a family moved to another CAU. When interpreting the results of the cluster analysis, it is necessary to realise that both methods, spatial and spatiotemporal scanning, provide estimates of local hot-spots and cold-spots. However, this does not have to be the case when compared to universal values such as a national target or national average.

Moreover, this report analysed records of fully immunised children only. It also used rates computed for CAUs based on the NIR and live births provided by Statistics New Zealand. The estimates of immunisation rates in less populated CAUs may therefore be less precise due to the confidentiality of data. For instance, in the case of the birth registry, random rounding to the base of three protected the privacy in the data. Finally, the selection of suitable parameters is crucial for the spatiotemporal

scan statistic. Combinations of other settings including spatial, temporal, and analytical parameters, were tested to evaluate the sensitivity of the method and results did not change considerably under any such parameter changes. Only larger and more populated clusters were identified as the result of aggregation. That means some of the local variations were hidden although the locations of primary clusters and their characteristics tend to be similar.

5. Conclusion

Our study used NIR data on over 4.4 million childhood immunisation events to examine nationwide spatiotemporal trends of immunisation coverage from 2006 to 2017. We identified areas of low immunisation coverage clustering across New Zealand. Although some of the identified clusters were only temporary, there are regions in New Zealand where low immunisation coverage is persistent which may indicate possible structural problems or inequities. Findings help policymakers to understand the development of childhood immunisation coverage in New Zealand and will inform effective future prevention strategies. In addition, an analysis of partial immunisations and vaccination hesitancy (both area-based and individual-based) could provide further insight.

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Conflict of interest

We declare no competing interests.

Key points

- National Immunisation Register was used to identify well and insufficiently immunised areas in New Zealand over time.
- Some of the identified clusters were only temporary, however there are regions in New Zealand where low immunisation coverage is persistent which may indicate possible structural problems or inequities.
- Findings help policymakers to understand the development of childhood immunisation coverage in New Zealand and will inform effective future prevention strategies.

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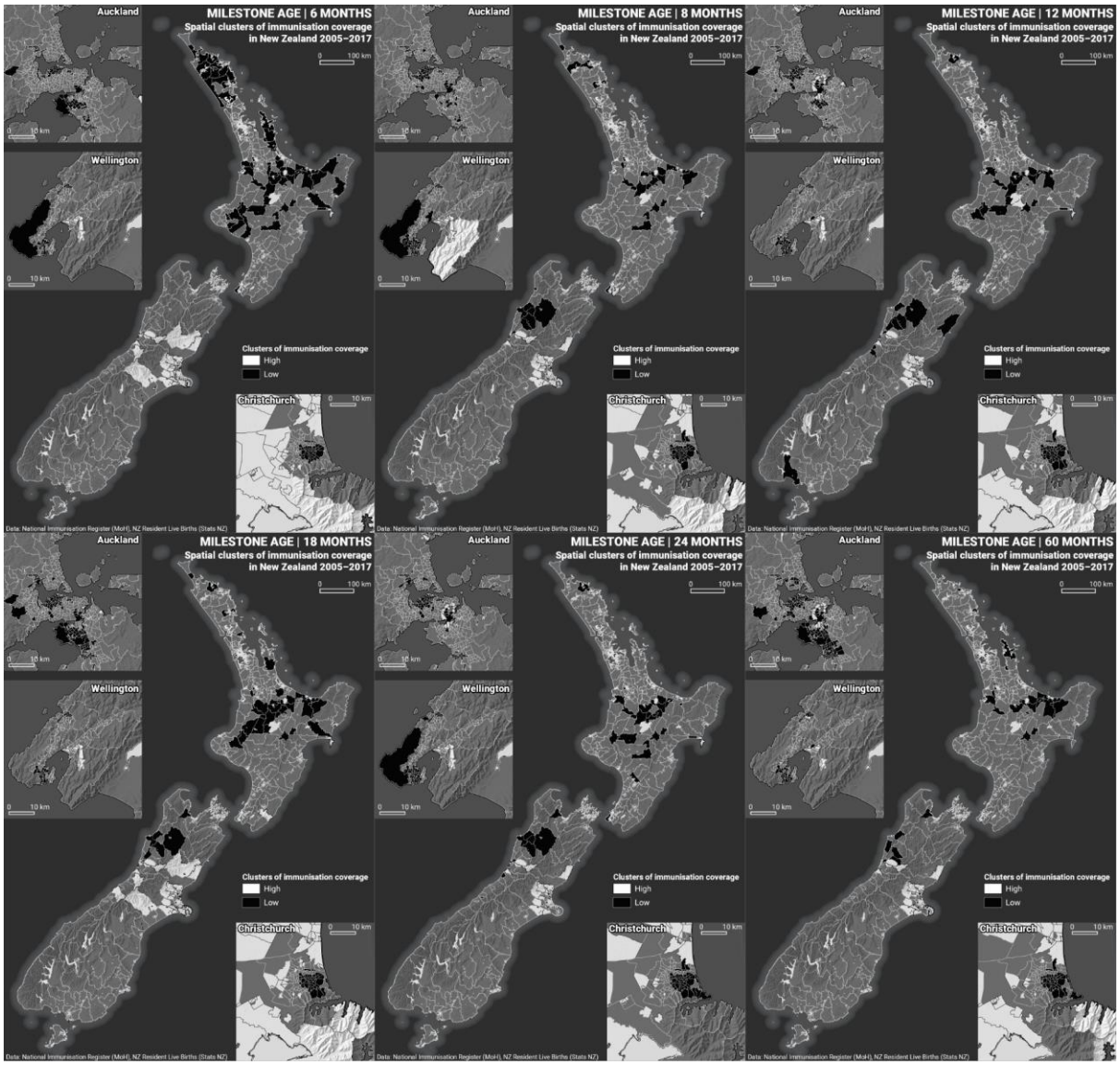


Figure 1 Hot- and cold-spots of average immunisation coverage by milestone age

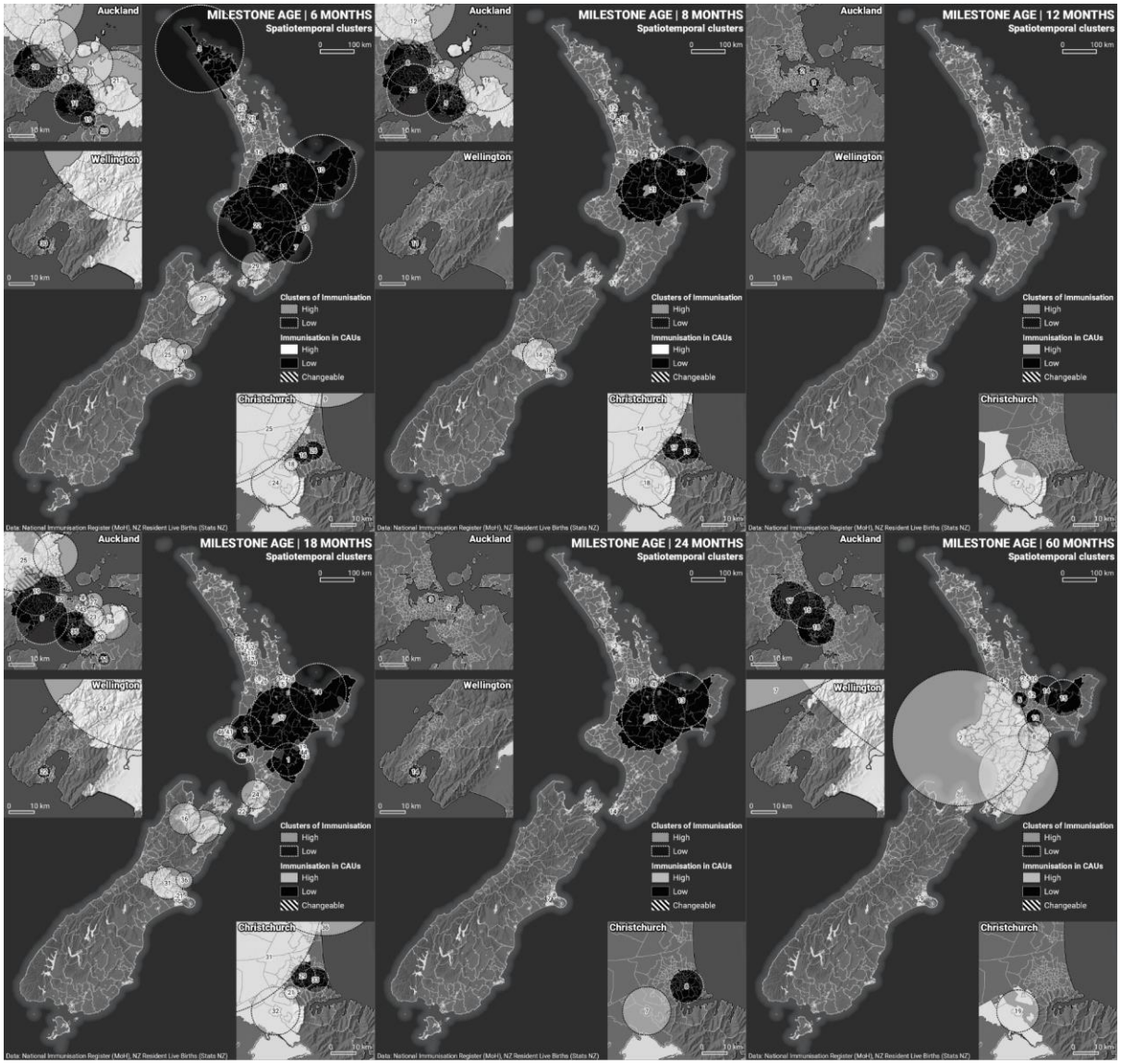


Figure 2 Geovisualisation of spatiotemporal clusters of immunisation coverage in New Zealand

Online supplementary material

Supplementary Table 1 Properties of spatiotemporal clusters at 6-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2006	2012	60	16923	15018	High
2	2006	2015	16	3375	4609	Low
3	2008	2017	73	12662	14796	Low
4	2006	2012	37	10257	8563	High
5	2006	2014	3	1113	560	High
6	2006	2015	6	2274	1461	High
7	2006	2012	10	1145	1433	Low
8	2006	2011	10	1593	940	High
9	2006	2014	22	3177	2118	High
10	2006	2017	99	21582	24797	Low
11	2006	2015	65	36398	40431	Low
12	2006	2017	152	27550	31028	Low
13	2006	2017	7	1368	1006	High
14	2006	2014	30	8832	11614	Low
15	2006	2013	3	1161	834	High
16	2006	2014	33	6760	8850	Low
17	2006	2017	3	690	417	High
18	2006	2017	8	3378	2256	High
19	2007	2014	18	8853	10039	Low
20	2006	2015	9	3411	4163	Low

21	2006	2014	33	11973	8817	High
22	2006	2011	172	15313	16766	Low
23	2006	2014	48	13915	10940	High
24	2006	2015	11	4104	1875	High
25	2007	2016	69	15272	11398	High
26	2006	2014	30	6536	9694	Low
27	2007	2016	28	6242	5125	High
28	2007	2016	88	38210	41066	Low
29	2007	2016	81	17152	15482	High
30	2006	2014	24	3304	4366	Low
31	2006	2017	2	1449	920	High

Supplementary Table 2 Properties of spatiotemporal clusters at 8-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2006	2015	2	1584	1051	High
2	2006	2017	2	1719	1078	High
3	2006	2011	18	5193	4044	High
4	2006	2015	3	1185	691	High
5	2007	2014	65	35787	39777	Low
6	2006	2014	3	1221	643	High
7	2006	2008	10	1056	542	High
8	2007	2016	99	50579	54824	Low
9	2006	2015	6	2757	1739	High
10	2007	2016	16	4054	5636	Low
11	2006	2015	24	4269	5852	Low
12	2006	2014	48	16229	13057	High
13	2006	2014	30	11144	13885	Low
14	2007	2014	69	14166	10488	High
15	2006	2017	9	3243	3937	Low
16	2006	2013	33	11976	9054	High
17	2006	2015	53	14092	17752	Low
18	2006	2015	11	4602	2184	High
19	2006	2014	40	10325	14819	Low
20	2006	2013	6	3126	2388	High
21	2006	2011	117	11385	12910	Low
22	2006	2011	71	8578	9899	Low

23	2007	2016	97	50410	53874	Low

Supplementary Table 3 Properties of spatiotemporal clusters at 12-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2006	2012	6	2724	2049	High
2	2007	2015	16	3729	5422	Low
3	2006	2009	117	7274	8330	Low
4	2006	2010	71	7424	8371	Low
5	2006	2015	2	1626	1082	High
6	2007	2013	20	5498	6619	Low
7	2007	2015	11	4587	2141	High
8	2006	2015	3	1251	712	High
9	2007	2016	10	6087	7603	Low
10	2006	2017	2	1737	1097	High
11	2006	2015	6	2877	1811	High
12	2007	2014	30	11328	13669	Low

Supplementary Table 4 Properties of spatiotemporal clusters at 18-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2007	2009	29	1753	2050	Low
2	2016	2016	10	56	110	Low
3	2007	2012	3	426	790	Low
4	2007	2015	5	2397	1757	High
5	2007	2017	2	1623	1110	High
6	2008	2016	28	6316	5219	High
7	2007	2013	36	10851	9409	High
8	2007	2014	6	3021	2277	High
9	2008	2016	97	42396	45393	Low
10	2007	2014	4	701	448	High
11	2007	2017	9	4395	5155	Low
12	2008	2016	9	2223	2825	Low
13	2007	2017	8	3049	2465	High
14	2007	2017	38	8045	9188	Low
15	2007	2017	3	657	398	High
16	2008	2016	25	4442	3642	High
17	2007	2009	117	4843	5769	Low
18	2007	2017	20	7374	9005	Low
19	2008	2016	99	42322	46146	Low
20	2007	2015	3	1149	630	High
21	2008	2016	8	2631	1771	High
22	2007	2015	24	3583	4940	Low

23	2007	2013	27	8089	6810	High
24	2007	2017	81	20743	18685	High
25	2007	2015	26	5960	4832	High
26	2007	2017	3	1233	731	High
27	2007	2010	14	2052	1400	High
28	2007	2017	2	1461	903	High
29	2007	2015	53	11568	15035	Low
30	2007	2017	16	3885	5691	Low
31	2008	2016	69	14968	11317	High
32	2007	2017	11	4884	2439	High
33	2007	2015	40	9727	13977	Low
34	2007	2017	6	2805	1824	High
35	2007	2017	65	44941	49870	Low
36	2008	2015	22	3375	2203	High
37	2007	2017	30	13263	16280	Low
38	2007	2015	15	7440	5489	High
39	2007	2017	5	789	566	High
40	2010	2017	3	389	242	High
41	2007	2013	24	4181	3603	High
42	2007	2014	6	441	665	Low
43	2007	2014	3	972	1316	Low
44	2008	2016	4	1176	872	High
45	2007	2017	7	1393	1029	High
46	2007	2015	7	969	690	High

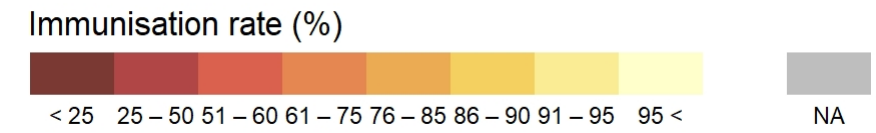
Supplementary Table 5 Properties of spatiotemporal clusters at 24-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2007	2015	6	3543	2771	High
2	2008	2014	20	5473	6491	Low
3	2008	2016	16	3417	5298	Low
4	2007	2017	2	1713	1172	High
5	2007	2012	3	414	851	Low
6	2007	2017	2	1539	948	High
7	2008	2016	11	4410	2091	High
8	2007	2015	54	13727	19229	Low
9	2007	2017	19	9732	11654	Low
10	2007	2017	6	2976	1948	High
11	2007	2017	3	1338	779	High
12	2007	2017	9	3039	3600	Low
13	2007	2010	78	6031	6786	Low
14	2007	2017	24	4648	6550	Low
15	2007	2017	12	2074	1591	High
16	2007	2010	117	7197	8080	Low

Supplementary Table 6 Properties of spatiotemporal clusters at 60-months milestone age

ID	Start	End	CAUs	Observed	Expected	Cluster type
1	2011	2017	223	39585	36111	High
2	2010	2017	6	2088	1255	High
3	2010	2017	3	957	438	High
4	2010	2017	28	8930	11223	Low
5	2010	2017	9	2403	2945	Low
6	2014	2017	16	999	1286	Low
7	2011	2017	259	39112	36984	High
8	2011	2017	19	2719	2182	High
9	2010	2017	2	1170	815	High
10	2010	2017	2	1026	644	High
11	2012	2017	3	486	359	High
12	2013	2017	4	336	219	High
13	2010	2017	3	59	133	Low
14	2011	2017	29	5211	5817	Low
15	2013	2017	20	2026	2383	Low
16	2011	2017	103	32674	37666	Low
17	2011	2017	99	32290	37573	Low
18	2011	2017	63	26645	31969	Low
19	2011	2017	8	2529	978	High

Supplementary Figure 1 (Animated) Immunisation coverage in New Zealand (2006–2017) by year and milestone age
https://1drv.ms/u/s!Akcs8gpB37mPgdd4IphlUFmFINWRzw?e=PDj7jL



Supplementary Figure 2 (Animated) Geovisualisation of spatiotemporal clusters of immunisation coverage in New Zealand by milestone age

https://1drv.ms/u/s!Akcs8gpB37mPgdd6F4T2NN2Ac1sLSA?e=5gIaF6